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Reduction of green house gas emission by clean power trading

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Keywords

Clean power trading, CO2 emission, Energy policy

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Reduction of green house gas emission by clean power trading

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Abstract-It is well known that the CO_2 emitted by fossil energy is one of the major reasons that result in global warming. It is still an open question about how to reduce CO_2 emission by the implementation of an investment plan for clean power systems. In this paper, we propose a clean power trading method among neighboring regions such that we can reduce CO_2 emission in a large region and reduce the imbalance between the power demand and supply in a region caused by the fluctuation of clean energy. With the five states with rich wind energy in America as an example, we use the quantitative computation results of the five states (from a modeling framework designed by ourselves [3]) to show that our proposed clean power trading method can help reduce CO_2 emission and realize balance.

Keywords: Clean power trading, CO_2 emission, Energy policy

1 Introduction

It has been well known that fossil energy has caused serious problems to our environment such as global warming. Among all reasons that lead to temperature increasement, fossil fuels play an important role. The estimation of Energy Information Administration [7] of Department of Energy in U.S.A. has shown that in 2006 the primary sources of energy consisted of petroleum 36.8%, coal 26.6% and natural gas 22.9%. The total value of these sources is 86.3% share for fossil fuels in primary energy production in the world. Burning fossil fuels produces about 21.3 billion tons of CO_2 every year. But, about only half of that amount can be absorbed by natural processes. Thus, there is a net increase of 10.65 billion tons of atmospheric CO_2 every year [10]. Now, CO_2 has become one of the major greenhouse gases that contribute to global warming and it causes the average surface temperature of the Earth to rise. This can lead to some adverse effects, which include global warming, sea level rise, and higher frequency of some extreme weather events. The ecosystems are vulnerable to these climate changes. [11]

As a major component of energy industry, power generation is a primary source that produces CO_2 emission. It is right time to find out how to avoid the above adverse effects by replacing fossil power with clean power. Some countries have proposed some strategies to reduce CO_2 emission. For example, RPS (Renewable Portfolio Standard) [1] has been approved by 27 states and D.C. in U.S.A. It has set up a goal to realize a specified fraction of clean power in the power generation market of some states in U.S.A. by a specified future year. For example, in Minnesota, 25% power generation should come from clean energy by 2025. Different states have different goals. Thus, it is necessary to design an investment plan about how to stimulate clean power development in the regions with rich renewable sources, such as wind energy in the Midwest area of America. In the plan, we should figure out how to minimize investment cost of clean power capacity expansion meanwhile meet the power demand of the region. Because of the fluctuation of renewable energy, the strategy should be able to maintain the balance of power demand and supply of a region. On the base of the above strategy requirements, we propose our clean power trading method.

First, we partition a whole region that needs to be planned for clean power systems into sub-regions such that each sub-region has some clean energy sources and power demand. Each sub-region's investment plan about clean power development is modeled by a linear programming (LP) and a mixed integer linear programming (MILP) model. Because of the fluctuation of clean energy such as wind energy, some sub-regions may have surplus power and other sub-regions cannot satisfy their local power demand without doing fossil power capacity expansion. In this case, the clean power trading can be done between sub-regions with surplus power and the sub-regions that need power to meet its local power demand. This trading mechanism not only satisfies the power demand of each sub-region but also help reduce the CO_2 emission in the whole region.

Some related works have been done in this area. One of them is WinDS (Wind Deployment Systems Model) [4] developed by SEAC (Strategic Energy Analysis Center) of NREL (National Renewable Energy Lab). This model focuses on the market issues about transmission access and cost, and the fluctuation of wind power. Another model is All-Modular Industry Growth Assessment (AMIGA) model [6], which is a comprehensive economic model of energy markets. There are also other energy models such as MARKAL (MARKet ALlocation) [12] and NEMS [5]. All above related works do not consider clean power trading between neighboring regions. This disables the possibility of allowing clean power trading among different regions such that we can use this method to reduce CO_2 emission in the whole region.

2 Models

In this work, we do the clean power trading for five states (ND,SD,NE,MN,IA) in America because this region has rich wind energy [2]. We use this region as an example to show how to use clean power trading to reduce CO_2 emission. In the modeling tool designed by ourselves [3], we define each state as a sub-region, which has existing fossil power capacity and some potential wind energy. For each sub-region, we set up a HLM (hour level model) that is responsible for doing optimization computation at hour level because the balance between power demand and power supply must be planned at hour level. We also design a YLM (year level model) that is responsible for doing optimization computation for fossil or clean power capacity expansion because this kind of planning is at year level. The computation results of wind power supply in HLM are accumulated together to form the year level wind power supply, which are used to find the percentage value of the wind power supply out of the total power supply in the sub-region. The percentage value is used to compare with the specified clean power percentage value in RPS policy of the sub-region. If it is less than the value indicated by RPS, the YLM is solved to find how to do the wind power capacity expansion for the current year in the sub-region such that the RPS policy can be realized. Then, the HLM models are solved again with the new capacity expansion solved by YLM of the same sub-region. If the RPS is still not realized, the YLM model will be solved again for more clean power capacity expansion and then the HLM will be solved again to check whether RPS policy is realized. The HLM and YLM models will not be solved for the next year until RPS policy is realized for the current year in the sub-region.

2.1 Nomenclature [3]

(A1) Sets and Indices :

T	the set of hours in a day from 1 to 24		t	$t \in T$ for hour-level model, $t \in Y$ for year-level model
k	a future hour, $k \in T$		Y	the set of years from 2010 to 2049
y	the current year, $y \in Y$		z	a future year, $z \in Y$
S	the set of load sub-regions in Midwest area		i	a load sub-region $i \in S$
j	a load sub-region $j \in S$			

(A2) Objective function variables :

PV_{it}	the total price volatility caused by the difference between power supply and power demand in S of load sub-region i in period t
CO_{it}	the total CO_2 emission cost of load sub-region i in period t/ [$]
IC_{it}	the total investment cost of wind and fossil power plant capacity expansion of load sub-region i in in period t. [$]
OC_{it}	the total operation and management cost of wind and fossil power plant of load sub-region i in period t. [$]
TC_{it}	the total cost of transmission lines built up for transmitting wind power from power plants to its closest existing power grids of load sub-region i in in period t. [$]

(A3) Parameters about the cost of investment, operation, transmission :

IC^{wp}_{iy}	the investment cost of wind power plants of load sub-region i in year y. [$/MW]
IC^{fp}_{iy}	the investment cost of fossil power plants of load sub-region i in year y. [$/MW]
IC^{h}_{iy}	the investment cost of heating storage of load sub-region i in year y. [$/MW]
OC^{wp}_{iy}	the operation cost rate of a wind power plant of load sub-region i in year y. [$/MW]
OC^{fp}_{iy}	the operation cost rate of a fossil power plant of load sub-region i in year y. [$/MW]
OC^{h}_{iy}	the operation cost rate of heating storage of load sub-region i in year y. [$/MW]
TC^{w}_{iy}	the cost of transmission lines corresponding to wind power capacity expansion of load sub-region i in year y. [$/MW]
TC^{fp}_{iy}	the cost of transmission lines corresponding to fossil power capacity expansion of load sub-region i in year y. [$/MW]

(A4) Decision variables:

CE^{wp}_{it}	the capacity expansion of wind power plants of load region i in period t. [MW]
CE^{fp}_{it}	the capacity expansion of fossil power plants of load sub-region i in period t. [MW]
CE^{wh}_{it}	the capacity expansion of heating storage of wind power plants of load sub-region i in period t. [MW]
PS^{fp}_{it}	the power supply from fossil power plants of load sub-region i in period t. [MW]
PS^{wp}_{it}	the power supply from wind power plants of load sub-region i in period t. [MW]
PS^{wh}_{it}	the power supply from the heating storage of wind power plants of load sub-region i in period t. [MW]
PB_{it}	the power bought from the stored surplus wind power of other load sub-regions to load region i in period t.
BB_{it}	the binary variable that indicates whether the load sub-region i needs to buy power from other sub-regions.
R^{wh}	the percentage of stored power released from storage systems of wind power plants.

(A5) Other parameters:

PD_{it}	the power demand of load sub-region i in period t. [MWh]
CO^{fp}_{it}	the cost of CO_2 emission of fossil power plants of sub-region i in period t. [$/MW]
PN_{it}	the power that can be bought from the neighboring sub-regions of i in the period t.
PO^{wp}_{it}	the output power generated by the wind turbines in wind power plants is the minimal value among existing wind power plant capacity and total available wind power of load sub-region i at time t.
SP^{wh}_{it}	the surplus power stored in the heating storage of wind power plants of load sub-region i in period t. [MW]
EC^{fp}_{iy}	the existing fossil power plant capacity of load sub-region i in year y. [MW]
EC^{wp}_{iy}	the existing wind power plant capacity of load sub-region i in year y. [MW]
η^{h}_{it}	the transformation efficiency rate of heating storage of load sub-region i in period t. In year level model, it is η^{h}_{iy}.
TWP^{A}_{it}	the total potential wind power that can be captured by wind turbines of load sub-region i in period. t. In year model, it is TWP^{A}. In year level, level model, it is TWP^{A}_{iy}. [MW]
RPS_{it}	the percentage of clean power in the total power supply of load region i in period t.
TF_{iy}	the transmission factor of load sub-region i in year y. It expresses the limitation of transmission systems on the wind power that can be transmitted online in real time. $0 < TF_{iy} \leq 1$
DR^{w}_{it}	the discount rate of funding invested on wind energy development of load sub-region i in period t.
DR^{f}_{it}	the discount rate of funding invested on fossil energy development of load sub-region i in period t.

2.2 YLM (Year Level Model)

The YLM_i (year level model) in [3] is responsible for doing optimization computation of wind power development in sub-region i at year level. It mainly focuses on satisfying the clean power market share requirements of RPS policy in sub-region i by doing fossil or wind power capacity expansion at year level. The YLM's objective is to minimize the cost of investment for capacity expansion, transmission cost, CO_2 emission and operation cost. The linear programming model of the YLM_i year level model is as follows:

min $IC_{iy} + CO_{iy} + TC_{iy} + OC_{iy}$ (1)

s.t.

$PS_{iy}^{fp} + PS_{iy}^{wp} + PS_{iy}^{wh} + PB_{iy} = PD_{iy}$ (2)

$PS_{iy}^{fp} \leq EC_{iy}^{fp} + CE_{iy}^{fp}$ (3)

$PS_{iy}^{wp} \leq (EC_{iy}^{wp} + CE_{iy}^{wp}) \times TF_{iy}$ (4)

$PS_{iy}^{wh} \leq \eta_{iy}^{h} \times (EC_{iy}^{wh} + CE_{iy}^{wh})$ (5)

$CE_{iy}^{wp} \leq (TWP^{A} - EC_{iy}^{wp})$ (6)

$(PS_{iy}^{wp} + PS_{iy}^{wh}) \geq RPS_{iy} \times (PS_{iy}^{fp} + PS_{iy}^{wp} + PS_{iy}^{wh})$ (7)

$(EC_{iy}^{wh} + CE_{iy}^{wh}) \leq (EC_{iy}^{wp} + CE_{iy}^{wp}) \times (1 - TF_{iy})$ (8)

$PS_{iy}^{wp} + PS_{iy}^{wh} \leq (EC_{iy}^{wp} + CE_{iy}^{wp} + EC_{iy}^{wh} + CE_{iy}^{wh}) \times TF_{iy}$ (9)

where:

$CO_{iy} = CO_{iy}^{fp} \times PS_{iy}^{fp}$ (10)

$TC = TC_{iy}^{w} \times (CE_{iy}^{wp} + CE_{iy}^{wh}) \times TF_{iy} + TC_{iy}^{fp} \times CE_{iy}^{fp}$ (11)

$IC = \frac{(IC_{iy}^{fp} \times CE_{iy}^{fp})}{DR_{iy}^{f}} + \frac{(IC_{iy}^{wp} \times CE_{iy}^{wp})}{DR_{iy}^{w}} + \frac{(IC_{iy}^{wh} \times CE_{iy}^{wh})}{DR_{iy}^{w}}$ (12)

$OC = (OC_{iy}^{fp} \times (EC_{iy}^{fp} + CE_{iy}^{fp})) + (OC_{iy}^{wp} \times (EC_{iy}^{wp} + CE_{iy}^{wp}))$
$+ (OC_{iy}^{wh} \times (EC_{iy}^{wh} + CE_{iy}^{wh}))$ (13)

2.3 HLM (Hour Level Model)

The HLM model in [3] is to minimize the imbalance caused by the power demand variation and wind power fluctuation and the CO_2 emission caused by fossil power generation at hour level. The HLM also satisfies its local power demand by fossil power, wind power, the power released from storage systems and the clean power bought from other sub-regions that have surplus stored wind power. The HLM is a mixed integer linear programming model because the sub-region i needs to decide whether it needs to buy power from other sub-regions in the case that its local power demand cannot be satisfied. The mixed integer linear programming model of the HLM_i hour level model is as follows:

min $PV_{it} + CO_{it}$ (14)

s.t.

$PS_{it}^{fp} + PS_{it}^{wp} + PS_{it}^{wh} + PB_{it} = PD_{it}$ (15)

$PS_{it}^{fp} \leq EC_{it}^{fp}$ (16)

$PB_{it} \leq BB_{it} \times PN_{it}$ (17)

$PS_{it}^{wh} \leq \eta_{it}^{h} \times SP_{i(t-1)}^{wh} \times R_{it}^{wh}$ (18)

$PS_{it}^{wp} \leq min\{EC_{it}^{wp}, TWP_{it}^{A}\} \times TF_{it}$ (19)

$PS_{it}^{wp} + PS_{it}^{wh} \leq (EC_{it}^{wp} + EC_{it}^{wh}) \times TF_{it}$ (20)

where:

$PV_{it} = 1 - \frac{PS_{it}^{fp} + PS_{it}^{wp} + PS_{it}^{wh}}{PD_{it}}$ (21)

$SP_{it}^{wh} = PO_{it}^{wp} - PS_{it}^{wp}$ (22)

$PO_{it}^{wp} = min\{EC_{it}^{wp}, TWP_{it}^{A}\}$ (23)

$CO_{it} = CO_{it}^{fp} \times PS_{it}^{fp}$ (24)

3 Computation Results of wind power trading

From the official websites of EIA [7], NERC [9] and FERC [8], we get the data sources about power demand, clean power fraction values of RPS policy, potential wind energy, existing fossil and wind power capacity installed before 2010.

In this section, we present the results of power trading among the five states. They trade stored wind power when the fossil power supply of some states is upperbounded by its local fossil power plant capacity and local wind power is fluctuating to low value at hour t. Moreover, the local power demand cannot be satisfied even though the stored surplus wind power has been released from its associated storage systems. The trading rule is that if a state needs to buy more power supply to satisfy its local power demand at hour t of year y, the states with more stored surplus wind power can sell this kind of power under the condition that its local power demand has been met. If the hungry state still cannot be satisfied even though it has got all stored surplus power from other states, it will buy fossil power to avoid blackout. Here, we assume that the fossil power can be got from a source outside the whole region.

We present the power trading among the five states in the table 1. In the table, **WB** is the wind power bought by a state, **SID** is the state selling wind power. **FB** is the fossil power bought by a state, **WS** is the wind power sold by a state, **BID** is the state buying wind power and [**MWh**] is megawatts-hour. **N/A** means that no seller sells wind power to the state or no buyers buy wind power from the state. From the table 1, we can find that the five states do not need to do any power trading before 2024 because they can satisfy their local power demand by their local fossil and wind power sources. The results also show that any one of five states need not to buy fossil power to avoid possible blackout. The states of ND, MN and IA are only power sellers, which means that they do not need to buy power from other states and their local fossil and wind power sources can satisfy their local power demand in the 40 years. But, NE and SD are not only power sellers but also power buyers, which means that they may need to buy wind power from other states in some hours of a year even though they can also provide some surplus power for sale in other hours of a year. This is caused by the hour-level fluctuation of wind energy in a state.

Moreover, the power trading among sellers and buyers is balanced, which means that the total power sold by sellers is equal to total power bought by buyers. For example, in 2037, the total power sold by ND, NE, SD, MN, and IA is $87,255$ MWh, which is the result of $20,639 + 4,997 + 652 + 29,424 + 31,543$ MWh. The total power bought by NE and SD is also $872,55$ $(6,527 + 80,728)$ MWh. Moreover, the table 1 shows that **FB** is 0 for all five states. From this, we can see that no states need to buy fossil power and they can satisfy their local power demand and the RPS requirements at the same time. The table 1 shows that only **SD** and **NE** need to buy power from other states during the period. From the values of **WB** of **SD** and **NE** in the table 1, we can calculate the CO_2 emission reduction of the whole region in the 40 years. In **SD**, the average CO_2 emission rate is 0.492148 (ton/MWh) and in **NE**, the rate is 0.63639 (ton/MWh) [7]. Without wind power trading, the power bought by **SD** and **NE** will have to be generated by fossil power plants. In **SD**, the total CO_2 emission is the product of total power bought by **SD** during the 40 years and its average CO_2 emission rate, which is $1,509,137\ MWh \times 0.492148\ ton/MWh = 742,720\ tons$. In the same way, we can get the result for **NE**, which is $3,753,444 \times\ 0.63639 = 2,388,700\ tons$. These results show that our wind power trading among regions can help reduce CO_2 emission $(742,720 + 2,388,700 = 3,131,400\ tons)$ for the whole region.

4 Conclusion

In this paper, we use the multi-function modeling tool developed by ourselves in [3] to present the computation results about wind power trading values of five states (ND,SD,NE,MN, IA) in Midwest area of America from 2010 to 2049. A primary contribution of this paper is that we use quantitative results to show that it is possible for a state to satisfy its local power demand by trading stored wind power between each other in the case that its total fossil and wind power system cannot provide enough power to satisfy its local demand. This not only avoids the possible blackout in a sub-region but also reduce CO_2 emission in the whole region, which is caused by buying fossil power from other places or doing its local fossil power capacity expansion. The results have shown that the fossil power trading is 0 in all five states for the 40 years from 2010 to 2049. The major contribution is that our wind power trading method can help reduce CO_2 emission in the whole region.

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	ND				
	power bought			power sold	
year	WB [MWh]	SID	FB [MWh]	WS [MWh]	BID
2024	0	N/A	0	189	SD
2025	0	N/A	0	579	SD
2026	0	N/A	0	908	SD
2027	0	N/A	0	1422	SD
2028	0	N/A	0	2081	SD
2029	0	N/A	0	2747	SD
2030	0	N/A	0	3512	SD
2031	0	N/A	0	7113	SD
2032	0	N/A	0	13960	SD
2033	0	N/A	0	21251	SD
2034	0	N/A	0	59542	SD
2035	0	N/A	0	39274	SD
2036	0	N/A	0	81987	SD
2037	0	N/A	0	20639	NE,SD
2038	0	N/A	0	29926	NE,SD
2039	0	N/A	0	34177	NE,SD
2040	0	N/A	0	30619	NE,SD
2041	0	N/A	0	37553	NE,SD
2042	0	N/A	0	53823	NE,SD
2043	0	N/A	0	76943	NE
2044	0	N/A	0	71947	NE
2045	0	N/A	0	90367	NE,SD
2046	0	N/A	0	129229	NE,SD
2047	0	N/A	0	124283	NE,SD
2048	0	N/A	0	164500	NE,SD
2049	0	N/A	0	163714	NE

	SD				
	power bought			power sold	
year	WB [MWh]	SID	FB [MWh]	WS [MWh]	BID
2024	1698	ND,NE,MN,IA	0	0	N/A
2025	5103	ND,NE,MN,IA	0	0	N/A
2026	8010	ND,NE,MN,IA	0	0	N/A
2027	11487	ND,NE,MN,IA	0	0	N/A
2028	15191	ND,NE,MN,IA	0	0	N/A
2029	20547	ND,NE,MN,IA	0	0	N/A
2030	25074	ND,NE,MN,IA	0	0	N/A
2031	49364	ND,NE,MN,IA	0	0	N/A
2032	88457	ND,NE,MN,IA	0	0	N/A
2033	135468	ND,NE,MN,IA	0	0	N/A
2034	230769	ND,NE,MN,IA	0	0	N/A
2035	156171	ND,NE,MN,IA	0	0	N/A
2036	340299	ND,NE,MN,IA	0	0	N/A
2037	80728	ND,NE,MN,IA	0	652	NE
2038	84316	ND,NE,MN,IA	0	4802	NE
2039	80454	ND,NE,MN,IA	0	7816	NE
2040	30423	ND,NE,MN,IA	0	12016	NE
2041	21950	ND,NE,MN,IA	0	15610	NE
2042	12904	ND,NE,MN,IA	0	23367	NE
2043	0	N/A	0	38755	NE
2044	0	N/A	0	55716	NE
2045	12806	ND,NE,MN,IA	0	62812	NE
2046	26048	ND,NE,MN,IA	0	82596	NE
2047	32545	ND,NE,MN,IA	0	73322	NE
2048	39352	ND,NE,MN,IA	0	93199	NE
2049	0	ND,NE,MN,IA	0	97098	NE

	NE				
	power bought			power sold	
year	WB [MWh]	SID	FB [MWh]	WS [MWh]	BID
2024	0	N/A	0	80	SD
2025	0	N/A	0	250	SD
2026	0	N/A	0	397	SD
2027	0	N/A	0	603	SD
2028	0	N/A	0	893	SD
2029	0	N/A	0	1149	SD
2030	0	N/A	0	1439	SD
2031	0	N/A	0	2862	SD
2032	0	N/A	0	5627	SD
2033	0	N/A	0	8636	SD
2034	0	N/A	0	13402	SD
2035	0	N/A	0	8993	SD
2036	0	N/A	0	21230	SD
2037	6527	ND,SD,MN,IA	0	4997	SD
2038	46608	ND,SD,MN,IA	0	5775	SD
2039	66143	ND,SD,MN,IA	0	5106	SD
2040	101926	ND,SD,MN,IA	0	1941	SD
2041	136365	ND,SD,MN,IA	0	1392	SD
2042	209857	ND,SD,MN,IA	0	830	SD
2043	317299	ND,SD,MN,IA	0	0	SD
2044	311703	ND,SD,MN,IA	0	0	SD
2045	367112	ND,SD,MN,IA	0	834	SD
2046	501070	ND,SD,MN,IA	0	1699	SD
2047	458078	ND,SD,MN,IA	0	2153	SD
2048	600797	ND,SD,MN,IA	0	2778	SD
2049	629959	ND,SD,MN,IA	0	0	SD

	MN				
	power bought			power sold	
year	WB [MWh]	SID	FB [MWh]	WS [MWh]	BID
2024	0	N/A	0	854	SD
2025	0	N/A	0	2616	SD
2026	0	N/A	0	4110	SD
2027	0	N/A	0	5662	SD
2028	0	N/A	0	7139	SD
2029	0	N/A	0	9509	SD
2030	0	N/A	0	11277	SD
2031	0	N/A	0	21414	SD
2032	0	N/A	0	36754	SD
2033	0	N/A	0	55203	SD
2034	0	N/A	0	80970	SD
2035	0	N/A	0	54159	SD
2036	0	N/A	0	117587	SD
2037	0	N/A	0	29424	NE,SD
2038	0	N/A	0	43161	NE,SD
2039	0	N/A	0	46105	NE,SD
2040	0	N/A	0	40356	NE,SD
2041	0	N/A	0	46515	NE,SD
2042	0	N/A	0	63810	NE,SD
2043	0	N/A	0	88990	NE
2044	0	N/A	0	79371	NE
2045	0	N/A	0	96327	NE,SD
2046	0	N/A	0	131182	NE,SD
2047	0	N/A	0	117885	NE,SD
2048	0	N/A	0	153609	NE,SD
2049	0	N/A	0	148833	NE

	IA				
	power bought			power sold	
year	WB [MWh]	SID	FB [MWh]	WS [MWh]	BID
2024	0	N/A	0	575	SD
2025	0	N/A	0	1658	SD
2026	0	N/A	0	2595	SD
2027	0	N/A	0	3800	SD
2028	0	N/A	0	5078	SD
2029	0	N/A	0	7142	SD
2030	0	N/A	0	8846	SD
2031	0	N/A	0	17975	SD
2032	0	N/A	0	32116	SD
2033	0	N/A	0	50378	SD
2034	0	N/A	0	76855	SD
2035	0	N/A	0	53745	SD
2036	0	N/A	0	119495	SD

	IA				
	power bought			power sold	
year	WB [MWh]	SID	FB [MWh]	WS [MWh]	BID
2037	0	N/A	0	31543	NE,SD
2038	0	N/A	0	47260	NE,SD
2039	0	N/A	0	53393	NE,SD
2040	0	N/A	0	47417	NE,SD
2041	0	N/A	0	57245	NE,SD
2042	0	N/A	0	80931	NE,SD
2043	0	N/A	0	112591	NE
2044	0	N/A	0	104669	NE
2045	0	N/A	0	129578	NE,SD
2046	0	N/A	0	182412	NE,SD
2047	0	N/A	0	172980	NE,SD
2048	0	N/A	0	226063	NE,SD
2049	0	N/A	0	220314	NE

Table 1: The results of power trading in ND, SD, NE, MN and IA